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PRESSURE SENSOR

Background Information

The present invention is directed to a pressure sensor according to the definition of the species in the main claim. Micromechanical silicon pressure sensors are known, a  
5 diaphragm being created by inserting a cavern into a silicon chip. Such a silicon sensor is disclosed in Unexamined Patent Application DE 199 57 556, for example. In this case, the cavern is created via anisotropic KOH etching for example.

Advantages of the Invention

10 The pressure sensor according to the present invention having the features of the main claim has the advantage over the related art that a simple and cost-effective design is proposed for the manufacture of a pressure sensor. The pressure sensor according to the present invention is used in  
15 particular for measuring high pressures, the pressure sensor according to the present invention nonetheless exhibiting significant overload safety. Furthermore, it is also possible according to the present invention to use the pressure sensor for low pressures. The pressure sensor according to the  
20 present invention therefore has the advantage that cost-effective manufacture of a micromechanical sensor for low to high pressures (e.g., up to or over 1,000 bar) is possible. As a result, it is possible to cost-effectively provide a pressure sensor which is usable for a wide range of different  
25 pressures. This makes it possible to increase the quantities while further lowering costs. Moreover, the system according to the present invention makes it possible to separate the pressure medium and the analyzing circuit. It is particularly advantageous that the connections between the first and the

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second fixing area are only pressure-stressed. This means that the force action, which acts on the diaphragm area for measuring a pressure, has the effect that the first fixing area is pressed onto the second fixing area.

- 5 Advantageous refinements of and improvements on the pressure sensor recited in the main claim are possible due to the measures listed in the subclaims.

It is particularly advantageous that semiconductor material and/or bulk micromechanics is/are used to manufacture the pressure sensor element, thereby making it possible to manufacture the pressure sensor element and thus the pressure sensor in a particularly cost-effective and reliable manner. Furthermore, it is an advantage that the pressure sensor is provided for high pressures up to approximately 1,000 bar or for high pressures exceeding 1,000 bar. Because of this and the usability in a wide pressure range, the pressure sensor is manufacturable particularly cost-effectively and in large quantities. Furthermore, it is an advantage that the fixing element, with respect to its coefficient of thermal expansion, is designed to be adapted to the sensor element. This makes it possible that, due to temperature fluctuations, only minor stresses are applied to the sensor element and that the pressure sensor is usable not only in a wide pressure range but also in a wide temperature range. It is also advantageous that a connecting material is provided between the first fixing area and the second fixing area, the connecting material being comparatively soft. As a result, mechanical stresses due to temperature fluctuations are also able to be effectively compensated for. Furthermore, it is an advantage that resistor elements are provided in the diaphragm area, thereby making it possible to measure pressures in wide pressure ranges via simple means and thus in a cost-effective manner. Furthermore, it is advantageous that the connecting

surface between the first fixing area and the second fixing area is provided to be parallel or inclined, i.e., at an acute angle, with respect to the diaphragm plane, thereby resulting in manifold possibilities for varying the pressure sensor according to the present invention. It is also advantageous that the cross section of the fixing element tapers in the direction of the second fixing area. This makes it possible in a simple manner to assemble the sensor chip in a centered position.

## 10 Drawing

Exemplary embodiments of the present invention are illustrated in the drawing and explained in greater detail in the subsequent description.

- Fig. 1 shows a known micromechanical silicon pressure sensor according to the related art,
- Fig. 2 shows a pressure sensor according to the present invention as an absolute pressure sensor,
- Fig. 3 shows a pressure sensor according to the present invention as a relative pressure sensor,
- Fig. 4 shows different intermediate steps for manufacturing the sensor element,
- Fig. 5 shows a first design variant of the sensor according to the present invention, and
- Fig. 6 shows a second design variant of the sensor according to the present invention.

## Detailed Description of the Exemplary Embodiments

Figure 1 shows the generally common design of micromechanical silicon pressure sensors. A silicon substrate 110 is provided with a cavern 152 which creates a diaphragm which is not indicated in detail by a reference numeral. Silicon substrate 110 is connected to a glass 150 which is provided with a bore

and is soldered onto a socket 120 via a solder 160. Socket 120 as a single piece is connected to a pressure connecting piece. Furthermore, measuring shunts (not indicated in detail by a reference numeral), which are situated on the top side of silicon substrate 110, are connected to a terminal post 130 via one or multiple contact wires 132, the terminal posts being electrically isolated from socket 120 by a glass insulation 131. Cavern 152 of silicon substrate 110 has a typical etch bevel which has approximately the shape of the frustum of a pyramid. This results in a trapezoidal cross section. This frustum of a pyramid-shaped recess underneath the sensor diaphragm results when a silicon substrate is used which has a (100)- orientation since KOH etching exhibits different etching rates in different crystal directions. It proves to be disadvantageous in the known pressure sensor that the frustum of a pyramid-shaped recess at its greatest cross section, i.e., at the backside of the silicon substrate, is essential as the pressure application surface. This results in great tensile forces acting on glass 150 and solder 160. Consequently, the silicon sensor according to the related art has only a comparatively low burst pressure. Pressure sensors are frequently manufactured using bulk micromechanics and are anodically bonded on glass. For backside pressurization, the sensor is soldered onto a punched socket. The glass and the connecting points silicon/glass and glass/solder/socket are heavily tension-loaded so that pressure loads over 100 bar are difficult to implement. Expensive design concepts are used for higher pressures, some of which use a metal diaphragm (e.g., a thin-layer on a metal diaphragm, micromechanical pressure sensor having an oil seal).

Figure 2 shows a pressure sensor according to the present invention. A pressure sensor element 10, which is made in particular of a semiconductor material and in particular of

silicon, has a diaphragm area 12 on one front. On the backside of diaphragm area 12, an etched cavern 52 is created in pressure sensor element 10, the cavern being inserted into pressure sensor element 10 from the backside using a trench etching technique in particular. In Figure 2, measuring shunts are indicated on diaphragm area 12 of pressure sensor element 10 by reference numeral 16 and are, however, not represented in the following figures for the sake of simplicity, but are to be kept in mind. In Figure 2, pressure sensor element 10 has a fixing area 14 in the area of its backside which is referred to in the following as first fixing area 14. Pressure sensor chip 10, i.e., pressure sensor element 10, is manufactured in the embodiment shown in Figure 2 in particular in such a way that it has lateral projections 17 via which it may be fixed in or on a socket 20. This type of fixing results in the fact that only pressure stresses occur during pressurization. The force exerted on pressure sensor element 10 due to the pressurization is depicted in Figure 2 by an arrow and reference numeral 11.

For manufacturing the pressure sensor according to the present invention, pressure sensor element 10 is connected to socket 20, socket 20 also being referred to in the following as fixing element 20. Fixing element 20 also has a fixing area 22, in particular in the area of aforementioned projection 17, which is referred to in the following as second fixing area 22. A connecting material 15 is provided between first fixing area 14 and second fixing area 22. Solder (metal, glass) or adhesives may be used, for example, as connecting material 15. Socket 20 is preferably made of Kovar and is thus, with regard to its coefficient of thermal expansion, adapted to the coefficient of thermal expansion of the material of pressure sensor element 10, i.e., to silicon in particular. Since the preferred socket material Kovar is poorly machinable, socket

20 is preferably manufactured using metal injection molding technology. Connecting material 15 is preferably relatively soft in order to absorb mechanical stresses during temperature changes.

5 Figure 2 shows an embodiment of the pressure sensor according to the present invention as an absolute pressure sensor. A vacuum-tight cap 40 around the front of pressure sensor element 10 is provided in this case. In its lower part, socket 20 again includes a pressure connecting piece which is not  
10 indicated in detail with a reference numeral. Furthermore, measuring shunts 12, which are situated on the top side of pressure sensor element 10, are connected to one or multiple terminal post(s) 30 via one or multiple contact wires 32, the terminal posts being electrically isolated from socket 20 by a  
15 glass insulation 31. Cap 40 encloses a reference volume 41 which is provided in an evacuated manner, for example. The absolute pressure on the backside of pressure sensor element 10, i.e., the side of pressure sensor element 10 facing away from reference volume 41, may thus be measured.

20 Figure 3 shows a pressure sensor according to the present invention as a relative pressure sensor. Here again, pressure sensor element 10 is shown including its first fixing area 14 and its diaphragm area 12. Furthermore, socket 20 is shown including its second fixing area 22. Connecting material 15  
25 between first and second fixing areas 14, 22 and pressure force 11 or force action 11 acting on pressure sensor element 10 are also shown. A printed board, indicated by reference numeral 42, is shown in Figure 3. The electrical leads between printed board 42 and pressure sensor element 10 are  
30 implemented via contact wires 32. According to the present invention, printed board 42 may also be provided as hybrid 42.

Different intermediate steps for manufacturing sensor element 10 are shown in Figure 4. A substrate 50, in particular a semiconductor substrate 50 as the preferred material for sensor element 10, is processed according to known methods. In this case in particular, a cavern 52 is etched into the backside of future pressure sensor element 10 (see Figure 4a). According to the present invention, a trench etching technique or, as explained in connection with Figure 1, a KOH etching technique, is used in particular for this purpose. Due to etching of cavern 52, diaphragm area 12 is created in the area of the front of future pressure sensor element 10. In a preferred embodiment of the present invention, piezoresistive resistors on the diaphragm and, if needed, additionally an integrated analyzing circuit in substrate 50 alongside the diaphragm are created on the front of future pressure sensor element 10 prior to etching of cavern 52. However, neither the resistors nor the analyzing circuit is shown in Figure 4. A further step for manufacturing pressure sensor elements 10 is shown in Figure 4b: notches 54 are implemented from the front. Figure 4a and Figure 4b each represent a side view of pressure sensor element 10 according to the present invention along a cut through diaphragm area 12. According to the present invention, notches 54 are created in particular using etching techniques such as high-rate trench etching or sawing using a broad saw blade. The shape of the notches, such as square, round, etc., is freely selectable. Figure 4c shows a top view of a number of future pressure sensor elements 10 prepared in this way, diaphragm area 12 being particularly prominent.

Subsequent to these preparatory steps, the still connected (see Figures 4a-4c) pressure sensor elements 10 are separated. This is preferably carried out by sawing using a very thin saw blade. Pressure sensor element 10, obtained in this way and also referred to in the following as pressure sensor chip 10

or sensor chip 10, may be assembled in a socket 20 as shown in Figures 2 and 3.

Figures 5 and 6 show variants of a pressure sensor according to the present invention. As a first variant (shown in Figure 5), sensor chip 10 may be assembled without a notch, i.e., without projection 17 as shown in Figure 2. In this case, first fixing area 14 is situated at the edge of sensor chip 10 alongside diaphragm area 12 on the front of sensor chip 10. In this case, the socket preferably has a slanting guide which facilitates the centric assembly of pressure sensor chip 10.

In a second variant of the pressure sensor according to the present invention (shown in Figure 6), sensor chip 10, having a beveled saw angle, is manufactured using a special saw blade, thereby allowing self-centered chip assembly. This results in the fact that the connecting surface between first fixing area 14 and second fixing area 22 is inclined with respect to the plane of the diaphragm of sensor chip 10, i.e., forming an acute angle. According to the circumstances in Figures 2, 3, and 5, the mentioned connecting surface is parallel to the plane of the diaphragm of sensor chip 10.

In both variants of the pressure sensor according to the present invention, the backside of socket 20 is provided in such a way that the cross section of socket 20 tapers in the direction of second fixing area 22, thereby making the mentioned centric assembly of pressure sensor chip 10 possible.